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Invention: METHOD OF MEASURING SIGNAL TIMING, AND RADIO SYSTEM

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SPECIFICATION

METHOD OF MEASURING SIGNAL TIMING, AND RADIO SYSTEM

FIELD OF INVENTION

The field of the invention are radio systems and, more particularly, a
5 CDMA radio system. The invention relates to a method of measuring signal
timing to be used in the CDMA radio system comprising at least three base
stations and a terminal, which multiply a signal by a spreading code, and in
which method the transmission of a base station comprises various code
channels transmitted by different spreading codes, on one of which code
10 channels a predetermined symbol sequence is transmitted, and in which
method the terminal is in connection with at least one base station, on whose
timing the terminal stores data.

The invention also relates to a radio system, which is a CDMA radio
system in particular, comprising at least three base stations and a terminal
15 which are arranged to multiply a signal by a spreading code, in which radio
system the transmission of a base station comprises various code channels
transmitted by different spreading codes, at least one of which code channels
comprises a predetermined symbol sequence, and the terminal is in
connection with at least one serving base station, on whose timing the terminal
20 stores data.

BACKGROUND OF THE INVENTION

It is important to determine the precise propagation time delay for a
received signal in order to detect the signal and to locate a terminal, for
25 example. In order for the terminal to synchronize itself to the transmission of a
base station, each base station transmits a synchronizing signal on a sync
channel. The signal on the sync channel can be demodulated and detected
each time when a pilot signal is identifiable. On the sync channel, data on the
base station, the power and phase of the pilot signal and the amount of uplink
30 interference is transferred. Detecting symbols on a traffic channel is possible
when the connection between a transmitter and a receiver is synchronized.
The synchronized connection for its part means that the terminal is aware of
the propagation time delay for the signal.

In prior art solutions, code channels whose direction of transmission
35 is from a base station to a subscriber station, e.g. pilot channels, can be used

for synchronizing. The subscriber station can seek the code phase and then synchronize itself to the transmission of the base station and thus determine the signal timing of the base station. In the reverse direction of transmission from a subscriber station to a base station, the subscriber station begins

5   transmitting and the base station seeks the code phase and determines the signal timing of the terminal. In the direction of transmission from a subscriber station to a base station, a problem arises which is due to the distance between a subscriber station and a base station, i.e. a near-far problem. In locating a terminal, this problem is called a coverage problem. A terminal

10 located close to one base station is outside coverage areas of other base stations and it is not capable of hearing other base stations because of the interfering transmission of the nearby base station. As the travel time of a signal between the terminal and at least three base stations cannot be measured, the location of the terminal cannot thus be determined either.

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BRIEF DESCRIPTION OF THE INVENTION

It is thus an object of the invention to provide a method and an apparatus implementing the method, in such a way that the above problems can be eliminated. This is achieved by a type of method disclosed in the

20 introduction, which is characterized by conveying data on at least one code channel transmitted by at least one neighbour base station via a serving base station to the terminal, the terminal determining on the basis of said data the spreading code of at least one said code channel and an estimate of the symbol timing of each code channel in respect of the timing of the serving

25 base station, and the terminal utilizing on the basis of these data on the code channels at least some of the code channels of the neighbour base station to measure the signal timing of the neighbour base station.

The system of the invention is characterized in that the serving base station is arranged to convey data on at least one code channel

30 transmitted by at least one neighbour base station, the terminal is arranged to determine on the basis of said data at least the spreading code of at least one said code channel and an estimate of the symbol timing of each code channel in respect of the timing of the serving base station, and on the basis of data on the code channels the terminal is arranged to utilize at least some of the code

35 channels of the neighbour base station to measure the signal timing of the neighbour base station.

The method and system of the invention provide a plurality of advantages. Coverage is improved and a terminal can also synchronize itself to the transmission of neighbour base stations, which enables the locating of the terminal.

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BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in greater detail in connection with the preferred embodiments, with reference to the attached drawings, in which

10   Figure 1 shows a radio system,

Figure 2 shows traffic channels,

Figure 3 shows a block diagram of a receiver and

Figure 4 shows a block diagram of a RAKE receiver.

15   DETAILED DESCRIPTION OF THE INVENTION

The solution of the invention is applicable to a WCDMA radio system (Wideband Code Division Multiple Access) in particular, yet without restricting thereto.

Figure 1 shows a radio system comprising a terminal 100, three

20   base stations 102 to 106 and a base station controller 108. In this case, the terminal 100, which is preferably a mobile phone, can be considered primarily being in connection with the base station 102. Neighbour base stations of the base station 102 are the base stations 104 and 106. All these base stations 102 to 106 share preferably the same base station controller 108, from which

25   there is a further connection via e.g. a mobile services switching centre (not shown in Figure 1) to the other parts of the mobile telephone network and to other telephone networks. All the other parts of the radio system except the terminals 100 are defined as the network part of the radio system.

To measure the terminal location, the travel time of a signal

30   between the terminal and at least three base stations is needed. At first, the terminal measures the time of arrival, TOA, of a signal transmitted by each base station. Time differences between the signals of the base stations TDOA (Time Difference Of Arrival) or OTD (Observed Time Difference) can be detected by calculating the differentials of the times of arrival TOA of the base

35   stations, when the time differences also indicate the distances between the

base stations and the terminal. When the distances between the terminal and at least three base stations is known, the terminal location can be determined unambiguously. In the CDMA system, the time of arrival can be determined by utilizing the synchronization of the spreading code. When a given chip of the

5   spreading code (a chip is a bit of the spreading code) at the terminal appears at the instant t1 and the same chip at the base station appears at the instant t2, the travel time of the signal between the terminal and the base station is t2 - t1. The terminal measures the time t1 and the base station measures the time t2. In the solution of the invention, the terminal clock need not be

10 synchronized with the clocks of the base stations. When the terminal transmits a so-called round-trip signal to the base station and the base station replies to this signal, the effect of the time difference between the terminal and the base station can be eliminated. If the transmission of the base stations has not been synchronized and the time differences between the base stations are not

15 known, the round-trip must be measured from all the base stations whose signal timing the terminal measures. In a synchronized network, or if the time differences between the base stations are known, a round-trip signal is not needed for employing the TDOA method based on the time differences to determine a location. In the TOA method based on propagation time delays, a

20 round-trip signal is only needed for the serving base station.

Even if the network was synchronized or the timing differences between the base stations were known, the round-trip signal to the serving base station can be used in determining the range for the propagation time delay to the other base stations. The terminal first measures the distance to

25 the serving base station by using the round-trip signal. If the distance to the serving base station is d1, then the distance between the neighbour base station and the terminal is:

$$d12 - d1 - e \leq d2 \leq d12 + d1 + e$$

where d12 is the distance between the serving base station and the neighbour

30 base station and e is the accuracy of the measurement d1. The range of the delay established this way can be utilized in estimating the propagation time delay. The range deviation of the distance between the terminal and the neighbour base station is $2(d1 + e)$, which corresponds to $2(d1 + e)/(c^*Tc)$ as chips, where Tc is the duration of the chip and c is the velocity of

35 electromagnetic radiation.

In the solution of the invention, the terminal 100 is at first in connection with at least one base station (in Figure 1, with the base station 102). At request of the terminal 100 or the network part of the radio system, the neighbour base stations 104, 106 of the base station 102 serving the

5   terminal 100 transmit to the terminal 100 data on the transmitted code channels, an example of which is a traffic channel in particular. On the basis of the received data, the terminal 100 can also utilize some other than the sync channel in synchronizing, whereby it is possible to measure the signal timing of the neighbour base stations 104, 106 on higher interference and noise

10 levels than in the solutions solely based on the use of the sync channel, because also the energy of a signal of other than the sync channel can be used. It is especially preferable to utilize the parts of the code channels in which a known signal is transmitted, e.g. regularly transmitted reference i.e. pilot symbols. Thus, data modulation can be eliminated from these parts

15 without decision feedback, and a so-called coherent averaging or filtering can be used for the measured estimate of the impulse response of the channel. Let us now turn to the solution of the invention in case of using pilot symbols of the code channel.

An example of the content of the code channels transmitted by a

20 base station is shown as a function of time in Figure 2. In this example, predetermined pilot symbols 200 are transmitted on three different traffic channels CH1, CH2 and CH3 at different instances. In order to be capable of making use of the pilot symbols 200, the terminal has to be aware of the time difference Tslot between the pilot symbols of the code channel in respect of

25 the timing of the serving base station. On the traffic channel, besides data 204 also a transmission power symbol TPC (Transmission Power Control) is transmitted, by means of which symbol the base station can request the terminal to change its transmission power.

In order to make use of the signals of the code channel, the

30 terminal 100 has to have data both on the time difference Tslot between the pilot symbols 200 and on the spreading code, spreading coefficient and reference symbols of the code channel. The terminal 100 needs further an estimate of the phase of the spreading code and of the location of the reference symbols in a timeslot, which data the base station 102 serving the

35 terminal 100, the base station controller 108 or some other unit in the fixed network part requests of the neighbour base station 104, 106. The neighbour

base station 104, 106 transmits these data to the serving base station 102 preferably via the fixed network part from at least one of its code channels, which has/have the highest transmission power in the direction of the base station 102 serving the terminal. The base station 102 serving the terminal 100

5 transmits these data further to the terminal 100. Data on the signal timing are given to the terminal 100 preferably in respect of the timing of the serving base station 102. If the neighbour base station 104, 106 does not transmit a sufficient amount of code channels for the timing measurement to succeed, e.g. due to low congestion, the neighbour base station 104, 106 can add more

10 channels to the transmission for the time the terminal 100 is measuring the channels. This can also happen at request of the terminal 100. It is the signal timing of these channels that is used in the inventive solution to locate the terminal 100. On these channels used particularly in locating the terminal 100, known reference symbols are preferably transmitted. When a radio system is

15 only slightly congested, more channels can be added without substantially disturbing data transmission of other terminals. All the timings that are conveyed by the fixed network are preferably in respect of the timing of the serving base station 102.

Let us now take a closer look on a receiver of the terminal in Figure

20 3 applicable to the solution of the invention. The receiver comprises firstly an antenna 280, radio frequency parts 282 and an analogue-to-digital converter 284. A transmitted signal is received by the antenna 280, from which the signal travels to the radio frequency parts 282 where a quadrature demodulation is performed. In quadrature demodulation, the received signal is

25 divided into two parts, the first of which is multiplied by a radio-frequency cosine carrier wave, which has the form $\cos(\omega_c t)$. The second part of the signal is multiplied by a phase-shifted carrier wave, which can be expressed such that the signal is multiplied by a sin carrier wave, which has the form $\sin(\omega_c t)$. Thus, the multiplication of signals employs carrier waves, between

30 which there is a $\pi/2$ phase shift. As the different parts of the signal are orthogonal to each other due to the $\pi/2$ phase shift, data parts can be expressed in a complex manner. Thus, the received signal U can be expressed in the form $U = I + jQ$, where I is the first data part, Q is the second data part and j is an imaginary unit. The quadrature-demodulated signal parts

35 I, Q are changed in the analogue-to-digital converter 284 to complex digital samples.

A filter 300 arranged to the code of the received signal is a FIR filter (Finite Impulse Response), whose weight coefficients are directly derived from the spreading code of the used signal. The arranged filter 300 outputs the correlation of each signal received per each signal sample by means of one

5   delay to be measured along with the spreading code, which is loaded to the arranged filter 300 from a code generator 302. The arranged filter 300 comprises N taps, which corresponds to the delay area to be measured. As N signal samples have been driven through the arranged filter 300, the weight coefficients remaining unchanged, N correlation values have developed,

10 preliminarily indicating an estimate of the impulse response of the channel in vector format. From the preliminary estimate of the impulse response, the effect of data modulation in a multiplier 306 is eliminated, in which multiplier the preliminary estimate of the impulse response is multiplied by a predetermined symbol sequence derived from a symbol generator 304. Thus,

15 the estimate of the impulse response is made, and its biggest values generate delay estimations for multipath components of the signal. As the amount of noise in the signal is very high, before generating delay estimations, a series of consecutive estimates of the impulse response has to be filtered in calculating means 308 in order to establish reliable delay estimations. This is

20 accomplished by loading the weight coefficients of the arranged filter 300 to the next N samples of the spreading code and by averaging the N-long impulse response established this way with the previous estimates of the impulse response. After the coherent averaging according to the invention is performed for the estimates of the impulse response, the delay estimations for

25 the received signal can in principle be made. In the described receiver solution, delay estimations are, however, still specified by further processing. It is to be noticed that although the term coherent averaging is in this description connected to the estimates of the impulse response, any known filtering of the estimates of the impulse response, e.g. an IIR-based filtering (Infinite Impulse

30 Response), can be used instead of the averaging in the receiver implementing the inventive solution. If several code channels are used for measuring timing, their known symbol sequences can be utilized by loading to the arranged filter at each instant of time the coefficients corresponding to the spreading code of the code channel by which spreading code reference symbols are received at

35 that moment. If there is a sufficient amount of code channels in use and their time differences Tslot span the whole transmission period of the reference

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symbols, the terminal can after the arranged filter constantly use a signal from which data modulation can be eliminated. The estimates of the impulse response generated in this manner can be coherently averaged, providing that the code channels to be used in measuring timing are transmitted from the
5   same antenna of the base station, whereby they proceed along the same radio channel.

A complex IQ signal proceeds coherently from the averaging calculating means 308 to selecting means 310, at which also an output signal of the arranged filter 300 directly arrives. The selecting means 310 can thus be
10 used for deciding, whether or not to utilize the coherent averaging. Irrespective of the fact, whether to directly select the output signal of the filter 300 or to use the coherently averaged signal components, the signal in IQ format is squared (I^2+Q^2) in means 312 before the averaging in means 314 to eliminate data modulation and phase error. As data modulation, e.g. a QPSK modulation
15 (Quadrature Phase Shift Keying) is employed. The averaging which is performed after the selector 310 is called incoherent averaging. Employing only incoherent averaging according to the prior art has the disadvantage that besides the signal, also the noise in the output of the arranged filter 300 is squared, and thus the signal-to-noise ratio does not substantially improve after
20 the averaging. A mere incoherent averaging helps, however, to estimate the peaks more reliably. In coherent averaging, the squaring is performed only after the coherent averaging. This requires, however, that the transmitted symbols, preferably pilot symbols, are predetermined, whereby data modulation can be eliminated from the samples.
25   In practice, a frequency error between the transmitter and oscillators (not shown in the figures) in the radio frequency means 282 of the receiver and the Doppler shift in the signal caused by a radio channel create phase rotating of signal samples, and so the coherent averaging time cannot be very long, e.g. about 1 ms maximum. In this case, a coherently averaged
30 estimate of the impulse response can be squared and further averaged incoherently at a longer period of time (more than 1 ms) in the means 314. As the estimate of the impulse response proceeds to a delay estimator 316, the delay estimator 316 seeks the peaks of the estimate of the impulse response representing the most important delays of the multipath-propagated signal.
35 The shortest delay often corresponds to the time the signal has taken to travel the direct line of sight distance. In this way, the terminal can measure the time

of arrival TOA (Time Of Arrival) of the signals of the base stations and the observed time difference OTD (Observed Time Difference) between the signals. The receiver is controlled by a control unit 318 and blocks 300 to 318 form a delay block 298, which can be a part of a RAKE receiver.

5   Figure 4 shows a block diagram of a RAKE receiver. The received signal travels from the antenna 280 through the radio frequency means 282 and the analogue-to-digital converter 284 as in Figure 3. Thereafter, a complex signal travels to the delay block 298, which is illustrated in more detail in Figure 3, and to RAKE branches 400 to 404 of the RAKE receiver. The

10   blocks 400 to 404 typically comprise a code generator and an arranged filter to decode the spreading code, and each block 400 to 404 is arranged to edit the spreading-coded signal received at different delays. The delay block 298 sets the delays of the RAKE branches 400 to 404, by which the spreading coding is decoded. After the spreading codings of the signals received by the RAKE

15   branches 400 to 404 have been decoded, different signal components of the multipath-propagated signal are combined in a diversity combiner 406, after which the baseband processing of the signal is continued, but the further processing is not substantial for the inventive solution. In the receiver, the amplification and frequency of the radio frequency means 282 is preferably

20   adjusted by means of automatic gain control means 410 and by means of automatic frequency control means 412.

When it comes to digital signal manipulation in particular, the solutions of the invention can be implemented by e.g. ASIC or VLSI circuits (Application-Specific Integrated Circuit, Very Large Scale Integration). The

25   procedures to be performed are preferably implemented as programs based on microprocessor technology.

Although the invention has been described above with reference to the example according to the attached drawings, it is obvious that the invention is not restricted thereto, but may be modified in a variety of ways

30   within the scope of the inventive idea disclosed in the attached claims.